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Organic ice resist lithography with an environmental TEM

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In this work we use an environmental transmission electron microscope (ETEM) to investigate the resolution limits of Organic Ice Resist Lithography (OIRL) [1]. OIRL is a novel one-step method for patterning nanostructures. Fig 1(a) outlines the general principle of OIRL. First, the organic vapor condenses into a thin layer of ice on the substrate, which is held at cryogenic temperature. Then, the ice layer is exposed to the scanning electron beam. After beam exposure, the substrate is heated to room temperature and unexposed ice sublimates. The areas exposed to the electron beam are non-volatile and remain on the substrate.

The size of the generated pattern depends on several factors, one being the illumination characteristics. To minimize the instrumental limitation on the patterning resolution imposed by a broad spot, we used the optics offered by an ETEM operated at 80 kV in scanning mode.

We used simple linear hydrocarbons (N-alkanes) with different molecular weights as precursors. After adjusting deposition and beam exposure parameters, we patterned sub-10 nm features (Fig 1(b)). The experiments revealed that the feature size depends on the precursor molecular weight. Coupling this result with the experimental contrast curves of each precursor (exposed thickness vs. dose) led to a model capable of reproducing the observed line-width vs. molecular weight trends, which is an essential step towards developing an understanding of the physics behind OIRL.

We will also discuss a side-effect observed during our experiments, which could provide a new avenue to study beam-induced charging. Fig 1(c) shows three patterns obtained by scanning the electron beam with different dwell time per pixel. The discontinuities in the patterns are attributed to the sample jumps due to the accumulation and dissipation of charge.

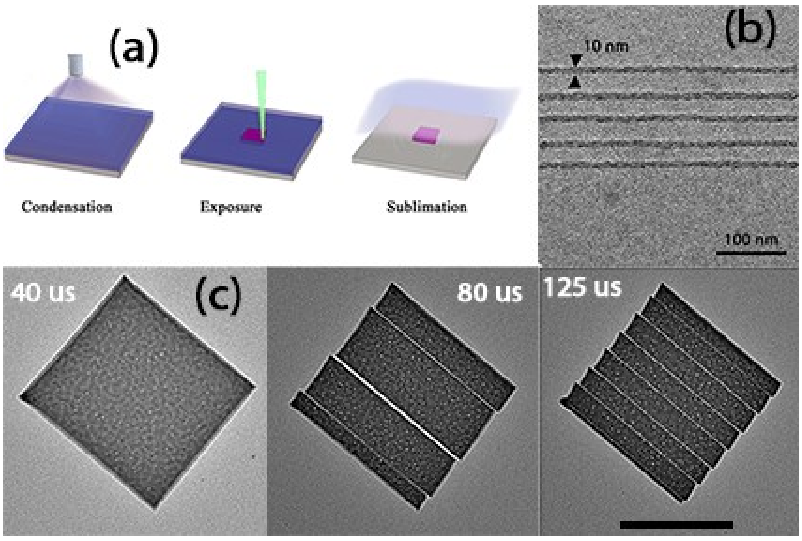

Figure 1(a) General principles of OIRL. (b) Patterned lines on hydrocarbon organic ice. (c) Areas patterned for various beam dwell time per pixel

[1] W. Tiddi, A. Elsukova, H.T. Le, P. Liu, M. Beleggia and A. Han, *Nano Letters* **17**, 7886–7891 (2017).